

station at Kakoma, in  $32^{\circ} 29' E.$ , and  $5^{\circ} 47' S.$ , in the plateau which begins at the boundary of Ugogo with the Mpwapa heights. The letters contain a good deal of information on the country and the people, the fauna, flora, and climate. Dr. Stecker gives an account of his Abyssinian journey, to which we have already referred. Herr Flegel gives a long account of his journey from Rubba, on the Niger, north to Sokoto and back, between October 1880 and April 1881. His map contains much new and useful information on the country traversed. Finally there are some letters from Herren Pogge and Wissmann, who had reached Malange in May, and hoped to be at Kimbundo in June.

#### FURTHER RESEARCHES ON ANIMALS CONTAINING CHLOROPHYLL<sup>1</sup>

IT is now nearly forty years since the presence of chlorophyll in certain species of Planarian worms was recognised by Schultze. Later observers concluded that the green colour of certain infusorians, of the common fresh-water hydra, and of the fresh water sponge was due to the same pigment, but little more attention was paid to the subject until 1870, when Ray Lankester applied the spectroscope to its investigation. He thus considerably extended the list of chlorophyll-containing animals, and his results are summarised in Sachs' Botany (Eng. ed.). His list includes, besides the animals already mentioned, two species of Radiolarians, the common green sea-anemone (*Anthea cereus*, var. *smaragdina*), the remarkable Gephyrean, *Bonellia viridis*, a Polychæte worm, *Chætoperus*, and even a Crustacean, *Idotea viridis*.

The main interest of the question of course lies in its bearing on the long-disputed relations between plants and animals; for, since neither locomotion nor irritability are peculiar to animals, since many insectivorous plants habitually digest solid food, since cellulose, that most characteristic of vegetable products, is practically identical with the tunicin of Ascidians, it becomes of the greatest interest to know whether the chlorophyll of animals preserves its ordinary vegetable function of effecting or aiding the decomposition of carbonic anhydride and the synthetic production of starch. For although it had long been known that *Euglena* evolved oxygen in sunlight, the animal nature of such an organism was merely thereby rendered more doubtful than ever. In 1878 I had the good fortune to find at Roscoff the material for the solution of the problem in the grass-green planarian, *Convoluta Schultzii*, of which multitudes are to be found in certain localities on the coast, lying on the sand, covered only by an inch or two of water, and apparently basking in the sun. It was only necessary to expose a quantity of these animals to direct sunlight to observe the rapid evolution of bubbles of gas, which, when collected and analysed, yielded from 45 to 55 per cent. of oxygen. Both chemical and histological observations showed the abundant presence of starch in the green cells, and thus these planarians, and presumably also *Hydra*, *Spongilla*, &c., were proved to be truly "vegetating animals."

Being at Naples early in the spring of 1879, I exposed to sunlight some of the reputedly chlorophyll-containing animals to be obtained there, namely, *Bonellia viridis* and *Idotea viridis*, while Krukenberg had meanwhile been making the same experiment with *Bonellia* and *Anthea* at Trieste. Our results were totally negative, but so far as *Bonellia* was concerned this was not to be wondered at, since the later spectroscopic investigations of Sorby and Schenck had fully confirmed the opinion of Lacaze-Duthiers as to the complete distinctness of its pigment from chlorophyll. Krukenberg, too, who follows these investigators in terming it *bonellein*, has recently figured the spectra of Anthea-green, and this also seems to differ considerably from chlorophyll, while I am strongly of the opinion that the pigment of the green crustaceans is, if possible, even more distinct, having not improbably a merely protective resemblance.

It is now necessary to pass to the discussion of a widely distinct subject—the long-outstanding enigma of the nature and functions of the "yellow cells" of Radiolarians. These bodies were first so called by Huxley in his description of *Thallassicolla*, and are small bodies of distinctly cellular nature, with a cell wall, well-defined nucleus, and protoplasmic contents saturated by a yellow

pigment. They multiply rapidly by transverse division, and are present in almost all Radiolarians, but in very variable number. Johannes Muller at first supposed them to be concerned with reproduction, but afterwards gave up this view. In his famous monograph of the Radiolarians, Haeckel suggests that they are probably secreting-cells or digestive glands in the simplest form, and compares them to the liver-cells of *Amphioxus*, and the "liver-cells" described by Vogt in *Velella* and *Porpita*. Later he made the remarkable discovery that starch was present in notable quantity in these yellow cells, and considered this as confirming his view that these cells were in some way related to the function of nutrition. In 1871 a very remarkable contribution to our knowledge of the Radiolarians was published by Cienkowski, who strongly expressed the opinion that these yellow cells were parasitic algae, pointing out that our only evidence of their Radiolarian nature was furnished by their constant occurrence in most members of the group. He showed that they were capable not only of surviving the death of the Radiolarian, but even of multiplying, and of passing through an encysted and an amoeboid state, and urged their mode of development and the great variability of their numbers within the same species as further evidence of his view.

The next important work was that of Richard Hertwig, who inclined to think that these cells sometimes developed from the protoplasm of the Radiolarian, and failing to verify the observations of Cienkowski, maintained the opinion of Haeckel that the yellow cells "für den Stoffwechsel der Radiolarien von Bedeutung sind." In a later publication (1879) he, however, hesitates to decide as to the nature of the yellow cells, but suggests two considerations as favouring the view of their parasitic nature—first, that yellow cells are to be found in Radiolarians which possess only a single nucleus, and secondly, that they are absent in a good many species altogether.

A later investigator, Dr. Brandt of Berlin, although failing to confirm Haeckel's observations as to the presence of starch, has completely corroborated the main discovery of Cienkowski, since he finds the yellow cells to survive for no less than two months after the death of the Radiolarian, and even to continue to live in the gelatinous investment from which the protoplasm had long departed in the form of swarm-spores. He sums up the evidence strongly in favour of their parasitic nature.

Meanwhile similar bodies were being described by the investigators of other groups. Haeckel had already compared the yellow cells of Radiolarians to the so-called liver-cells of *Velella*; but the brothers Hertwig first recalled attention to the subject in 1879 by expressing their opinion that the well-known "pigment bodies" which occur in the endoderm cells of the tentacles of many sea-anemones were also parasitic algae. This opinion was founded on their occasional occurrence outside the body of the anemone, on their irregular distribution in various species, and on their resemblance to the yellow cells of Radiolarians. But they did not succeed in demonstrating the presence of starch, cellulose, or chlorophyll. The last of this long series of researches is that of Hamann (1881), who investigates the similar structures which occur in the oral region of the Rhizostome jelly-fishes. While agreeing with Cienkowski as to the parasitic nature of the yellow cells of Radiolarians, he holds strongly that those of anemones and jelly-fishes are unicellular glands.

In the hope of clearing up these contradictions, I returned to Naples in October last, and first convinced myself of the accuracy of the observations of Cienkowski and Brandt as to the survival of the yellow cells in the bodies of dead Radiolarians, and their assumption of the encysted and the amoeboid states. Their mode of division, too, is thoroughly algaoid. One finds, not unfrequently, groups of three and four closely resembling *Protococcus*. Starch is invariably present; the wall is true plant-cellulose, yielding a magnificent blue with iodine and sulphuric acid, and the yellow colouring-matter is identical with that of diatoms, and yields the same greenish residue after treatment with alcohol. So, too, in *Velella*, in sea-anemones, and in meduse; in all cases the protoplasm and nucleus, the cellulose, starch, and chlorophyll, can be made out in the most perfectly distinct way. The failure of former observers with these reactions, in which I at first also shared, has been simply due to neglect of the ordinary botanical precautions. Such reactions will not succeed until the animal tissue has been treated with alcohol and macerated for some hours in a weak solution of caustic potash. Then, after neutralising the alkali by means of dilute acetic acid, and adding a weak solution of iodine, followed by strong sulphuric acid, the

<sup>1</sup> Abstract of a paper "On the Nature and Functions of the 'Yellow Cells' of Radiolarians and Coelenterates," read to the Royal Society of Edinburgh on January 14, 1882, and published by permission of the Council.

presence of starch and cellulose can be successively demonstrated. Thus, then, the chemical composition, as well as the structure and mode of division of these yellow cells, are those of unicellular algae, and I accordingly propose the generic name of *Philiozoon*, and distinguish four species, differing slightly in size, colour, mode of division, behaviour with reagents, &c., for which the name of *P. radiolarium*, *P. siphonophorum*, *P. actiniarium*, and *P. medusarum*, according to their habitat, may be conveniently adopted. It now remains to inquire what is their mode of life, and what their function.

I next exposed a quantity of Radiolarians (chiefly *Collozoum*) to sunshine, and was delighted to find them soon studded with tiny gas-bubbles. Though it was not possible to obtain enough for quantitative analysis, I was able to satisfy myself that the gas was not absorbed by caustic potash, but was partly taken up by pyrogallic acid, that is to say, that little or no carbonic acid was present, but that a fair amount of oxygen was present, diluted of course by nitrogen. The exposure of a shoal of the beautiful blue pelagic Siphonophore, *Velella*, for a few hours, enabled me to collect a large quantity of gas, which yielded from 24 to 25 per cent. of oxygen, that subsequently squeezed out from the interior of the chambered cartilaginous float, giving only 5 per cent. But the most startling result was obtained by the exposure of the common *Anthea cereus*, which yielded great quantities of gas containing on an average from 32 to 38 per cent. of oxygen.

At first sight it might seem impossible to reconcile this copious evolution of oxygen with the completely negative results obtained from the same animal by so careful an experimenter as Krukenberg, yet the difficulty is more apparent than real. After considerable difficulty I was able to obtain a large and beautiful specimen of *Anthea cereus*, var. *smaragdina*, which is a far more beautiful green than that with which I had been before operating—the dingy brownish-olive variety, *plumosa*. The former owes its colour to a green pigment diffused chiefly through the ectoderm, but has comparatively few algae in its endoderm; while in the latter the pigment is present in much smaller quantity: but the endoderm cells are crowded by algae. An ordinary specimen of *plumosa* was also taken, and the two were placed in similar vessels side by side, and exposed to full sunshine, by afternoon the specimen of *plumosa* had yielded gas enough for an analysis, while the larger and finer *smaragdina* had scarcely produced a bubble. Two varieties of *Ceriatis aurantiaca*, one with, the other without, yellow cells, were next exposed, with a precisely similar result. The complete dependence of the evolution of oxygen upon the presence of algae, and its complete independence of the pigment proper to the animal was still farther demonstrated by exposing as many as possible of those anemones known to contain yellow cells (*Aiptasia chamaeleon*, *Helianthus troglodytes*, &c.) side by side with a large number of forms from which these are absent (*Actinia mesembryanthemum*, *Sagastia parasitica*, *Cerianthus*, &c.). The former never failed to yield abundant gas rich in oxygen, while in the latter series not a single bubble ever appeared.

Thus, then, the colouring matter described as chlorophyll by Lankester has really been mainly derived from that of the endodermal algae of the variety *plumosa*, which predominates at Naples; while the Anthea-green of Krukenberg must mainly consist of the green pigment of the ectoderm, since the Trieste variety evidently does not contain algae in any great quantity. But since the Naples variety contains a certain amount of ordinary green pigment, and since the Trieste variety is tolerably sure to contain some algae, both spectroscopists have been operating on a mixture of two wholly distinct pigments—diatom-yellow and anthea-green.

But what is the physiological relationship of the plants and animal thus so curiously and intimately associated? Every one knows that all the colourless cells of a plant share the starch formed by the green cells; and it seems impossible to doubt that the endoderm cell or the Radiolarian, which actually incloses the vegetable cell, must similarly profit by its labours. In other words, when the vegetable cell dissolves its own starch, some must needs pass out by osmosis into the surrounding animal cell; nor must it be forgotten that the latter possesses abundance of amylolytic ferment. Then, too, the *Philiozoon* is subservient in another way to the nutritive function of the animal, for after its short life it dies and is digested; the yellow bodies supposed by various observers to be developing cells being nothing but dead alga in progress of solution and disappearance.

Again, the animal cell is constantly producing carbonic acid

and nitrogenous waste, but these are the first necessities of life to our alga, which removes them, so performing an intracellular renal function, and of course reaping an abundant reward, as its rapid rate of multiplication shows.

Nor do the services of the *Philiozoon* end here; for during sunlight it is constantly evolving nascent oxygen directly into the surrounding animal protoplasm, and thus we have actually foreign chlorophyll performing the respiratory function of native haemoglobin! And the resemblance becomes closer when we bear in mind that haemoglobin sometimes lies as a stationary deposit in certain tissues, like the tongue muscles of certain molluscs, or the nerve cord of *Aphrodite* and Nemerteans.

The importance of this respiratory function is best seen by comparing as specimens the common red and white *Gorgia*, which are usually considered as being mere varieties of the same species, *G. verrucosa*. The red variety is absolutely free from *Philiozoon*, which could not exist in such deeply-coloured light, while the white variety, which I am inclined to think is usually the larger and better grown of the two, is perfectly crammed. Just as with the anemones above referred to, the red variety evolves no oxygen in sunlight, while the white yields an abundance, and we have thus two widely contrasted physiological varieties, as I may call them, without the least morphological difference. The white specimen, placed in spirit, yields a strong solution of chlorophyll: the red, again, yields a red solution, which was at once recognised as being tetroxerythrin by my friend M. Merejkowsky, who was at the same time investigating the distribution and properties of that remarkable pigment, so widely distributed in the animal kingdom. This substance, which was first discovered in the red spots which decorate the heads of certain birds, has recently been shown by Krukenberg to be one of the most important of the colouring matter of sponges, while Merejkowsky now finds it in fishes and in almost all classes of invertebrate animals. It has been strongly suspected to be an oxygen-carrying pigment, an idea to which the present observation seems to me to yield considerable support. It is moreover readily bleached by light, another analogy to chlorophyll, as we know from Pringsheim's researches.

When one exposes an aquarium full of *Anthea* to sunlight, the creatures, hitherto almost motionless, begin to wave their arms, as if pleasantly stimulated by the oxygen which is being developed in their tissues. Specimens which I kept exposed to direct sunshine for days together in a shallow vessel placed on a white slab, soon acquired a dark, unhealthy hue, as if being oxygenated too rapidly, although I protected them from any undue rise of temperature by keeping up a flow of cold water. So, too, I found that Radiolarians were killed by a day's exposure to sunshine, even in cool water, and it is to the need for escaping this too rapid oxidation that I ascribe their remarkable habit of leaving the surface and sinking into deep water early in the day.

It is easy, too, to obtain direct proof of this absorption of a great part of the evolved oxygen by the animal tissues through which it has to pass. The gas evolved by a green alga (*Ulva*) in sunlight may contain as much as 70 per cent. of oxygen, that evolved by brown algae (*Halsis*) 45 per cent., that from diatoms about 42 per cent.; that, however, obtained from the animals containing *Philiozoon* yielded a very much lower percentage of oxygen, e.g. *Velella* 24 per cent., white *Gorgia* 24 per cent., *Ceriatis* 21 per cent., while *Anthea*, which contains most algae, gave from 32 to 38 per cent. This difference is naturally to be accounted for by the avidity for oxygen of the animal cells.

Thus, then, for a vegetable cell no more ideal existence can be imagined than that within the body of an animal cell of sufficient active vitality to manure it with carbonic acid and nitrogen waste, yet of sufficient transparency to allow the free entrance of the necessary light. And conversely, for an animal cell there can be no more ideal existence than to contain a vegetable cell, constantly removing its waste products supplying it with oxygen and starch, and being digestible after death. For our present knowledge of the power of intracellular digestion possessed by the endoderm cells of the lower invertebrates removes all difficulties both as to the mode of entrance of the algae, and its fate when dead. In short, we have here the relation of the animal and the vegetable world reduced to the simplest and closest conceivable form.

It must be by this time sufficiently obvious that this remarkable association of plant and animal is by no means to be termed a case of parasitism. If so, the animals so infested would be weakened, whereas their exceptional success in the struggle for

existence is evident. *Anthea cereus*, which contains most algae, probably far outnumbers all the other species of sea-anemones put together, and the Radiolarians which contain yellow cells are far more abundant than those which are destitute of them. So, too, the young gonophores of *Velella*, which bud off from the parent colony and start in life with a provision of *Philiozoon* (far better than a yolk-sac) survive a fortnight or more in a small bottle—far longer than the other small pelagic animals. Such instances, which might easily be multiplied, show that the association is beneficial to the animals concerned.

The nearest analogue to this remarkable partnership is to be found in the vegetable kingdom, where, as the researches of Schwendener, Bornet, and Stahl have shown, we have certain algae and fungi associating themselves into the colonies we are accustomed to call lichens, so that we may not unfairly call our agricultural Radiolarians and anemones *animal lichens*. And if there be any parasitism in the matter, it is by no means of the alga upon the animal, but of the animal, like the fungus, upon the alga. Such an association is far more complex than that of the fungus and alga in the lichen, and indeed stands unique in physiology as the highest development, not of parasitism, but of the reciprocity between the animal and vegetable kingdoms. Thus, then, the list of supposed chlorophyll-containing animals with which we started, breaks up into three categories: first, those which do not contain chlorophyll at all, but green pigments of unknown function (*Bonellia*, *Idotea*, &c.); secondly, those vegetating by their own intrinsic chlorophyll (*Convoluta*, *Hydra*, *Spongilla*); thirdly, those vegetating by proxy, if one may so speak, rearing copious algae in their own tissues, and profiting in every way by the vital activities of these.

PATRICK GEDDES

### SCIENTIFIC SERIALS

*Journal of the Royal Microscopical Society* for December, 1881, contains:—Diatoms from Peruvian guano, by Rev. L. G. Mills (plate xi.).—B. W. Richardson, on multiple staining and the usual summary of current researches relating to zoology and botany (principally Invertebrata and Cryptogamia).—Microscopy.—This part concludes volume i. ser. ii., and is accompanied by a very excellent index to the 980 pages, a list of authors, and full tables of contents.

*Transactions and Proceedings of the New Zealand Institute for 1880*, vol. xiii. Wellington, April, 1881.—In this large volume of over 460 pages, in addition to a short account of the proceedings of most of the scientific societies of New Zealand, the following memoirs are published *in extenso*:—*Astronomical*: H. Skey, on periodic vertical oscillations in the Sun's atmosphere, and their connection with the appearance and disappearance of the solar spots.—M. Chapman, on the permanency of solar and stellar heat.—A. W. Bickerton, on the causes tending to alter the eccentricity of planetary orbits.—On the origin of the solar systems.—On the origin of double stars.—On a simple method of illustrating the motions of the earth.—On the probability of impact.—*Zoological*: Julius von Haast, on *Balenoptera huttoni*, Gray.—On Harpagornis (3rd paper).—W. Arthur, on migratory salmon.—Dr. Hector, on a new fish.—F. E. Clark, on a new species of Trachypterus.—F. W. Hutton, contributions to New Zealand Malacology.—G. M. Thomson, New Zealand crustacea.—T. F. Cheeseman, new species of mollusca.—Prof. Liversidge, analysis of Moa egg-shell.—Capt. Broun, description of coleopterous larvae and pupæ.—T. W. Kirk, notes on birds.—On crustacea.—P. Buller, on new diurnal moths.—W. L. Buller, a new lizard.—T. Jeffery Parker, a new species of Chirodota.—On the venous system of the skate.—*Botanical*: W. Colenso, on the vegetable food of the ancient New Zealanders.—On the ferns of Scinde Island (Napier).—On some new ferns of New Zealand.—On a new species of Metzgeria.—G. M. Thomson, on fertilisation in New Zealand flowers.—On *Donatia novae-zealandiae*.—Dr. Berggren, on New Zealand plants.—T. F. Cheeseman, on the fertilisation of *Thelymitra*.—On a new Loranthus.—W. M. Marskell, New Zealand Desmids.—T. A. Mollet, on the structure of *Hormosira billardieri*.—Dr. Petrie, flora of Stewart Island.—On a new Carex.—T. B. Armstrong, on the genus Corallospantium.—On new or rare New Zealand plants.—On the occurrence of the Morel.—On a natural arrangement of the New Zealand ferns.—T. Kirk, some new plants.—Charles Knight, on a new Thysanothecium.—*Chemical*: W. Skey, on an allo-

tropic form of zinc and cobalt salts.—On a periodide and an iodo-carbonate of lead.—On the dimorphism of magnesia.—*Geological*: A. D. Dobson, on a dyke near Heathcote.—A. Hamilton, on the Foraminiferae of the tertiary beds at Petane.—A. M'Kay, on the genus Rhynconella.—S. Percy Smith, on changes in coast line level in the north of the North Island.—T. A. Mollet, on an artesian well at Avonside.—This volume is illustrated with eighteen lithographic plates.

*Zeitschrift für wissenschaftliche Zoologie*, Bd. 36, Part 2 (Nov. 1881), contains:—Prof. Hubert Ludwig, on the history of the development of the skeleton in Ophiuroids (plates x. and xi.).—Dr. Julius Andreæ, contribution to the anatomy and histology of *Sipunculus nudus*, L. (plates xii. and xiii.).—Dr. F. Mayser, comparative anatomy studies on the brain of osseous fishes, with especial reference to the Cyprinoids (plates xiv. to xxiii.).

*Atti della R. Accademia dei Lincei*, vol. vi., fasc. 1.—The reactions of biliary pigments, by S. Capranica.—Synthesis of naphtyl-acrylic acid, by F. Lugli.—Researches on the spider's web, by L. Valente.—On the light of the comet, by L. Respighi.

*Atti della R. Accademia dei Lincei*, vol. vi., fasc. 2.—On bilinear quaternary forms, by G. Battaglini.—On the origin of some linear differential equations, by S. Brioschi.—On the discharges of condensers, by Srs. Villari and Righi.—The endoptic perception of colour at the back of the eye, by C. Emery.—Contribution to the anatomy of leaves, by G. Brioschi.—On dimethyl-naphthaline, by G. Giovanozzi.—Reports, &c.

### SOCIETIES AND ACADEMIES

LONDON

*Royal Society*, December 8, 1881.—“On the Structure and development of *Lepidosteus*,” by F. M. Balfour, LL.D., F.R.S., and W. N. Parker.

The first section of this paper is devoted to the general development. In this section an account is given of the structure of the ripe ovum, of the segmentation, of the history of the germinal layers, of the first development of the principal organs, and of the external features of the embryo during embryonic and larval life. The more important points established in this section are—

1. The ovum when laid is invested by a double covering formed of (a) a thick inner membrane, the outer zone of which is radially striated, and (b) an outer layer made up of highly refractive pyriform bodies, which are probably metamorphosed follicular epithelial cells.

2. The segmentation is complete, though very unequal, the lower pole being very slightly divided up into segments, and its constituent parts fusing together again to form an unsegmented mass of yolk, like the yolk-mass of Teleostei.

3. The epiblast is divided into an epidermic and nervous stratum, as in Teleostei.

4. The walls of the brain, spinal cord, and optic vesicle are formed from a solid medullary keel, like that found in Teleostei.

5. The lens, the auditory vesicle, and olfactory pit, are wholly developed from the nervous layer of the epidermis.

6. The segmental or archinephric duct is developed as in Teleostei, from a hollow ridge of the somatic mesoblast, which becomes constricted off, except in front, thus forming a duct with an anterior pore leading into the body cavity.

The section on the general development is followed by a series of sections on the adult anatomy and development of various organs.

*The Brain*.—The authors give a fuller description of the adult brain than has previously been given. The new features in this description are (1) that the parts identified by previous anatomists as the olfactory lobes are really parts of the cerebral hemispheres, the true olfactory lobes being small prominences at the base of the olfactory nerves; (2) that there is attached to the roof of the thalamencephalon a peculiar vesicle, which has not hitherto been noticed, but which is similar to the vesicle found by Wiedersheim on the roof of the thalamencephalon of *Protopterus*. They further show that the cerebrum is divided into a posterior portion, with an unpaired ventricle, and an anterior portion in which the ventricle is paired. They consider the presence of the portion of the cerebrum with an unpaired ventricle to be an indication that this part of the brain retains characters which are only found in the embryonic brain of other groups. They point to the presence of lobi inferiores on the